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The ^{75}As(n,2n) Cross Sections into the ^{74}As Isomer and Ground State

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The ^{75}As$(n,2n)$ cross sections into the ^{74}As isomer and ground state

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The ^{75}As$(n,2n)$ cross section for the population of the $T_{1/2} = 26.8$-ns isomer at $E_x = 259.3$ keV in ^{74}As has been measured as a function of incident neutron energy, from threshold to $E_n = 20$ MeV. The cross section was measured using the GEANIE spectrometer at LANSCE/WNR. For convenience, the ^{75}As$(n,2n)$ population cross section for the ^{74}As ground state has been deduced as the difference between the previously-known $(n,2n)$ reaction cross section and the newly measured ^{75}As$(n,2n)^{74}$As^m cross section. The $(n,2n)$ reaction, ground-state, and isomer population cross sections are tabulated in this paper.

Partial γ-ray cross sections have been measured using the GEANIE spectrometer at LANSCE/WNR for the n + ^{75}As reaction [1]. The results for the ^{75}As$(n,2n)$ reaction, in particular, are tabulated and plotted in this paper.

The ^{75}As$(n,2n)$ reaction cross section has been extensively measured in prior experiments [2–17]. A calculation has been performed using the Hauser-Feshbach code STAPRE, and is in very good agreement with the existing data for $E_n \leq 14$ MeV (see Fig. 1). In fact, the STAPRE calculation is consistent with the data at all neutron energies, assuming a $\pm$ 10.4% systematic uncertainty in the calculation [20]. The STAPRE calculation of the ^{75}As$(n,2n)$ reaction cross section with the estimated systematic uncertainty is given in table I.

The $T_{1/2} = 26.8$-ns isomer at $E_x = 259.3$ keV in ^{74}As decays by a 76.2-keV γ ray with nearly a 100% branch. An alternate branch to the ground state may exist, but an upper bound of 3.8% has been placed on the branch [18]. The partial cross section of the $E_\gamma = 76.2$-keV transition has been measured using the GEANIE spectrometer. This is a model-independent estimate of the population cross section for this level. The photopeak counts measured at time t for this transition represent an integral up to time t of the decay of the isomeric state, populated by a white spectrum of incident neutron energies. To obtain the true photopeak counts (A), corresponding to a single incident neutron energy, the measured counts ($A^{(\mathrm{meas})}$) are corrected according to [1]

$$A = A^{(\mathrm{meas})} + \tau \frac{d}{dt} A^{(\mathrm{meas})} \tag{1}$$

where $\tau = 38.7$ ns is the lifetime of the isomeric level. In practice, the measured partial cross sections are binned in 12-ns steps, chosen to match the timing uncertainty in the data. The binning procedure and neutron-energy distribution within a given bin are discussed in [19]. The discrete binning of the data implies that the derivative in Eq. (1) must be replaced by a finite difference. There is always an ambiguity as to which two adjacent bins should be used to calculate each finite difference (i.e. next bin minus current, or current bin minus previous), and the effect can be seen in the negative values of the cross section near threshold in table II. To take this effect into account, a systematic uncertainty has been estimated from the difference in the $(n,2n)$ cross sections obtained by taking either choice of adjacent bins. The estimated uncertainty due to the isomer-effect correction in Eq. (1) varies from $\sim$ 20% at threshold to less than 10% near $E_n = 20$ MeV. Additional systematic uncertainties are due to the internal conversion coefficient, detector efficiencies, detector deadtimes, and unmeasured angular-distribution effects. These corrections contribute an additional 10.6% systematic uncertainty. The possible 3.8% branch to the ground state is also taken as a systematic uncertainty. All the systematic uncertainties are added in quadrature to form the total uncertainties listed in table II. The measured ^{75}As$(n,2n)^{74}$As^m cross section is plotted in Fig. 2 and compared to the STAPRE prediction. Above $E_n \approx 13$ MeV, the calculation overestimates the measured cross section, by as much as $\approx$ 25% near $E_n = 20$ MeV.

For convenience, the ^{75}As$(n,2n)$ cross section for the ^{74}As ground state has been obtained as the difference between the ^{75}As$(n,2n)$ reaction cross section, and the ^{75}As$(n,2n)^{74}$As^m population cross section. The resulting cross section is listed in table III, and compared to the STAPRE prediction in Fig. 3. The STAPRE calculation in this case agrees with the experimental cross section for $E_n \leq 13$ MeV, and underestimates it by as much as 12% near $E_n = 20$ MeV.

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TABLE I: ^{75}As$(n,2n)$ reaction cross section predicted by STAPRE, as a function of incident neutron energy E_n. A 10.4% systematic uncertainty, based on a comparison with independent measurements of the cross section, is shown in the third column.

E_n (MeV)	$\sigma(E_n)$ (barn)	Sys. err. (barn)
10.309	0.0000	0.0000
10.714	0.0130	0.0014
11.120	0.1041	0.0108
11.525	0.2587	0.0269
11.930	0.4250	0.0442
12.336	0.5773	0.0600
12.741	0.7091	0.0738
13.146	0.8213	0.0854
13.552	0.9157	0.0952
13.957	0.9938	0.1034
14.363	1.0567	0.1099
14.768	1.1060	0.1150
15.173	1.1435	0.1189
15.579	1.1711	0.1218
15.984	1.1906	0.1238
16.389	1.2036	0.1252
16.795	1.2116	0.1260
17.200	1.2156	0.1264
17.606	1.2167	0.1265
18.011	1.2156	0.1264
18.416	1.2129	0.1261
18.822	1.2090	0.1257
19.227	1.2032	0.1251
19.633	1.1934	0.1241
20.038	1.1771	0.1224

TABLE II: Measured ^{75}As$(n,2n)$ cross section into the $T_{1/2} = 26.8$-ns isomer at $E_x = 259.3$ keV in ^{74}As. The first and second columns give the centroid and standard deviation of the incident neutron energy distribution, respectively. The cross-section values are listed in the third column. The fourth column gives the statistical uncertainties, and the last column gives the total (statistical and systematic) uncertainties.

TABLE II: (Continued).

$\overline{E}_n$ (MeV)	σ_E (MeV)	$\sigma(E_n)$ (barn)	Stat. err. (barn)	Tot. err. (barn)
5.176	0.106	−0.0004	0.0004	0.0010
5.378	0.113	−0.0009	0.0006	0.0017
5.589	0.120	0.0007	0.0006	0.0037
5.814	0.126	−0.0018	0.0006	0.0021
6.047	0.133	0.0007	0.0006	0.0024
6.302	0.144	−0.0004	0.0006	0.0041
6.571	0.151	−0.0019	0.0006	0.0008
6.854	0.163	0.0008	0.0007	0.0010
7.160	0.171	0.0025	0.0007	0.0066
7.481	0.185	0.0005	0.0008	0.0028
7.833	0.198	0.0033	0.0009	0.0068
8.206	0.212	0.0044	0.0009	0.0123
8.606	0.228	0.0037	0.0010	0.0087
9.035	0.246	0.0098	0.0012	0.0164
9.502	0.265	0.0135	0.0014	0.0316
10.003	0.286	0.0122	0.0016	0.0156
10.539	0.308	0.0332	0.0019	0.0155
11.128	0.337	0.0631	0.0024	0.0156
11.771	0.367	0.1213	0.0031	0.0303
12.469	0.398	0.1852	0.0040	0.0500
13.220	0.438	0.2603	0.0051	0.0394
14.073	0.479	0.3057	0.0056	0.0467
14.975	0.528	0.3415	0.0060	0.0478
15.992	0.581	0.3681	0.0064	0.0433
17.098	0.641	0.3761	0.0063	0.0482
18.341	0.725	0.3886	0.0064	0.0487
19.744	0.800	0.3704	0.0059	0.0371

TABLE III: Deduced ^{75}As$(n,2n)$ cross section into the ^{74}As ground state. The table headers are the same as in table II.

$\overline{E}_n$ (MeV)	σ_E (MeV)	$\sigma(E_n)$ (barn)	Stat. err. (barn)	Tot. err. (barn)
5.176	0.106	0.0004	0.0004	0.0010
5.378	0.113	0.0009	0.0006	0.0017
5.589	0.120	−0.0007	0.0006	0.0037
5.814	0.126	0.0018	0.0006	0.0021
6.047	0.133	−0.0007	0.0006	0.0024
6.302	0.144	0.0004	0.0006	0.0041
6.571	0.151	0.0019	0.0006	0.0008
6.854	0.163	−0.0008	0.0007	0.0010
7.160	0.171	−0.0025	0.0007	0.0066
7.481	0.185	−0.0005	0.0008	0.0028
7.833	0.198	−0.0033	0.0009	0.0068
8.206	0.212	−0.0044	0.0009	0.0123
8.606	0.228	−0.0037	0.0010	0.0087
9.035	0.246	−0.0098	0.0012	0.0164
9.502	0.265	−0.0135	0.0014	0.0316
10.003	0.286	−0.0120	0.0016	0.0156
10.539	0.308	−0.0319	0.0019	0.0155
11.128	0.337	0.0436	0.0024	0.0192
11.771	0.367	0.2393	0.0031	0.0482
12.469	0.398	0.4376	0.0040	0.0819

TABLE III: (Continued).

$\overline{E}_n$ (MeV)	σ_E (MeV)	$\sigma(E_n)$ (barn)	Stat. err. (barn)	Tot. err. (barn)
13.220	0.438	0.5795	0.0051	0.0958
14.073	0.479	0.7076	0.0056	0.1153
14.975	0.528	0.7850	0.0060	0.1265
15.992	0.581	0.8228	0.0064	0.1312
17.098	0.641	0.8388	0.0063	0.1352
18.341	0.725	0.8249	0.0064	0.1353
19.744	0.800	0.8174	0.0059	0.1290

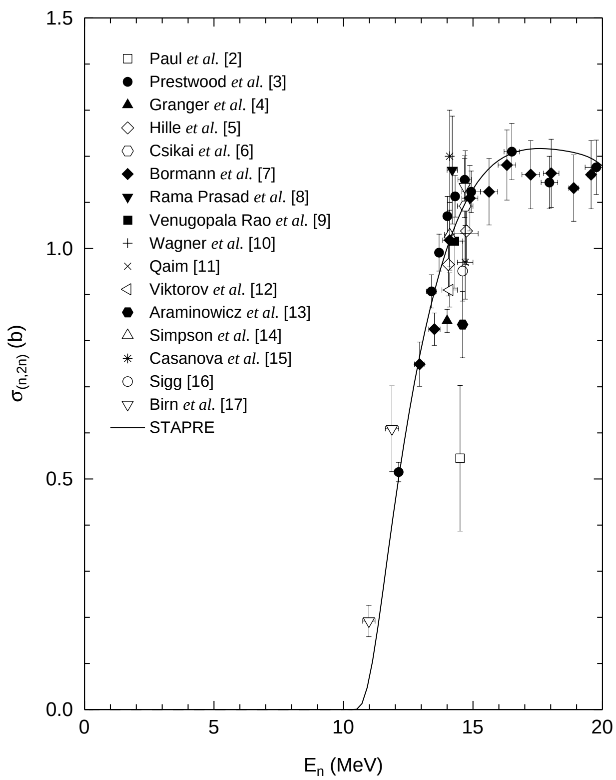

FIG. 1: ^{75}As$(n, 2n)$ reaction cross section measured in various independent experiments, and compared to the STAPRE prediction. The calculation is in good agreement with the data for $E_n \leq 14$ MeV, and systematically higher than the data for $E_n > 14$ MeV.

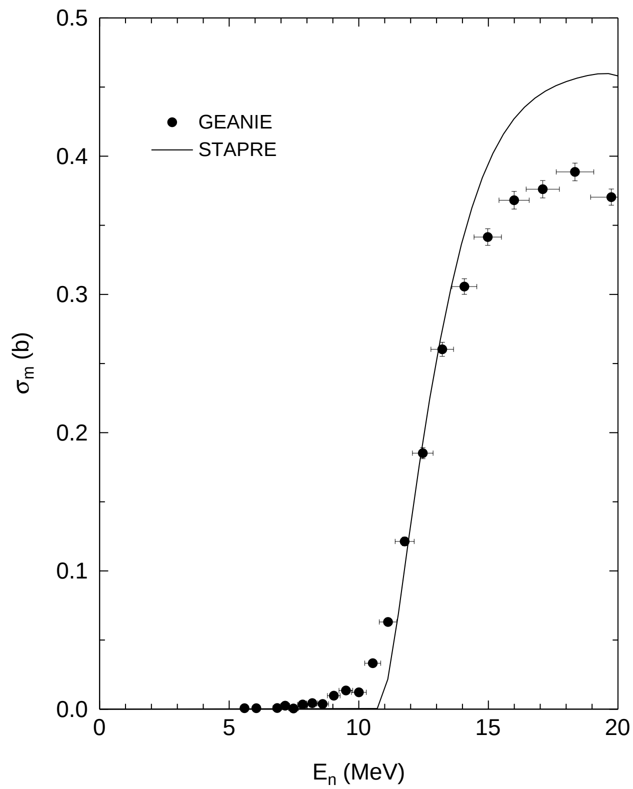

FIG. 2: The ^{75}As$(n, 2n)$ cross section into the $T_{1/2}$ = 26.8-ns isomer at E_x = 259.3 keV in ^{74}As, measured using GEANIE, and compared to the STAPRE prediction. Only statistical uncertainties are shown for the experimental data. The calculation agrees with the measurement below $E_n \approx 13$ MeV, and overestimates the data for $E_n > 13$ MeV.

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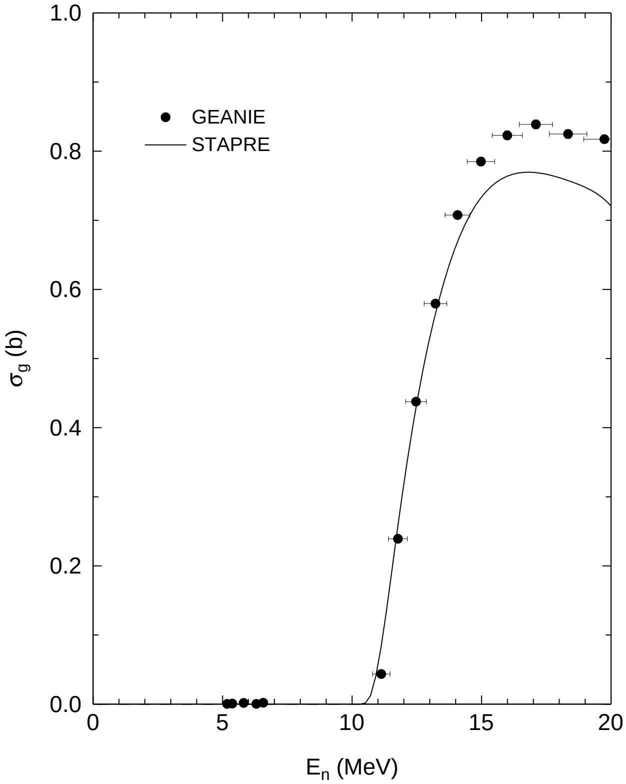

FIG. 3: The ^{75}As$(n, 2n)$ cross section into the ^{74}As ground state, deduced from the $(n, 2n)$ cross section into the isomer (shown in Fig. 2), and the $(n, 2n)$ reaction cross section calculated with STAPRE (shown in Fig. 1). Only statistical uncertainties are shown for the result. The calculation agrees with the measurement below $E_n \approx 13$ MeV, and underestimates the data for $E_n >$ 13 MeV.

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[20] To estimate the systematic uncertainty, the data points in Fig. 1 were interpreted as the mean and standard deviation of a Gaussian distribution, and 1000 values were sampled from each distribution. Next, a confidence band was expanded about the STAPRE curve by scaling it by factors $1 + k$ and $1 - k$, where k was increased from zero in small steps until 68.3% of the sampled points fell inside the confidence band. The value $k = 10.4\%$ was obtained through this procedure.